Study of the Dependences of Specific Energy Consumption on the Elements of the Cutting Mode as an Informative Parameter of the Cutting Process

Eldor Tursunovich Mamurov
Fergana polytechnic institute, Uzbekistan, Fergana

Annotation

The article considers the issues of using the dependence of specific energy consumption on the elements of the cutting mode as an informative parameter of the metal cutting process when creating high-performance technologies in automated production.

Keywords: *cutting theory, plastic deformation, cutting force, structural steels, specific energy consumption, chip shrinkage, tool material, cutting speed, machining, cutting power.*

Studies show the high information content of the cutting process parameters, such as cutting force and power. Determination of the cutting force by the calculation method was one of the first tasks that the science of cutting materials solved.

One of the founders of the theory of metal cutting, scientist K.A. Zvorykin, proceeding from the position that the cutting force is equal to the resistance of the metal of the workpiece being machined, the plastic deformation of chip formation and the friction force on the surfaces of the cutter, derived a theoretical equation for the cutting force. The conclusion was based on design schemes that reflect the work of a planer tool moving relative to the workpiece at a speed V. Based on the premise of the equality of forces simultaneously acting on the cutter and in the shearing plane, K.A. Zworykin derived the theoretical equation for the cutting force:

$$P = \frac{ab\tau\left[\left(1 - f_1^2\right)\cos\gamma + 2 f_1 \sin\gamma\right]}{\sin\Theta\left[\left(1 - f_1 f_2\right)\cos\left(\gamma - \Theta\right) + \left(f_1 + f_2\right)\sin\left(\gamma - \Theta\right)\right]}, \text{N} \quad (1)$$

The works of A.M. Rozenberg, I.M. Klushin, N.N. Zorev, M.F. Poletik, V.A. Krivoukhov are devoted to the system of acting reduced forces, the specifics of plastic deformation of chip formation, as well as the geometric shape of the maximum plastic deformation zone, replacing the concept of a shearing plane.

The cutting force equation proposed by these authors is inaccurate, since their conclusions were based on many omissions in the analysis of physical and mechanical processes in the cutting zone and are complex in form, and therefore have not been widely used.

G.I. Granovsky proposed a simplified cutting force equation

$$P = K\rho\delta_{\hat{A}} f_H, \text{N} \quad (2)$$

where: $\delta_{\hat{A}}$ - tensile strength of the processed material;

f_H - cross-sectional area of the cut layer, mm^2.

The product $K\rho\delta_{\hat{A}}$ expresses the specific resistance of the workpiece material to cutting. It has been experimentally established that when cutting carbon structural steels *Kr*≈2.5. For other grades of structural steels, depending on their chemical composition, structural state and mechanical properties, the coefficient *Kp*≈2.3-2.8.

The proposed equation for the cutting force makes it possible to estimate the value of the force acting in the cutting process only in the first approximation and cannot be used in accurate calculations.

V.F. Bobrov proposed to use empirical generalized formulas for calculating the cutting force components, which include cutting mode parameters - depth, feed and speed directly, and other factors indirectly. The formula contains correction factors that take into account the influence of the mode parameters acting on the forces, and the determination of which under production conditions is not associated with great difficulties. The general form of these formulas is represented as a dependence:

$$P = C_p t^{xp} S^{up} V^{zp} K_p \text{, N} \qquad (3)$$

These dependencies are quite simple and convenient, and therefore they are widely used in engineering calculations, however, due to the fact that they give very approximate and averaged results, it is not advisable to use them explicitly for the adaptive control problem.

Let us analyze the influence of the elements of the cutting mode on the specific energy consumption ***e*** of the cutting process. To do this, we determine at what values of cutting conditions the condition is satisfied $\frac{\partial e}{\partial V} = 0$, assuming the following empirical model

$$\frac{\partial e}{\partial v} = -4383{,}6\frac{S}{V^2} + 4{,}376\frac{1}{StV^2} = 0$$

since $V \neq 0$, then $S^2 t \cong 0.001$

In Fig.1. curves of dependence of specific energy consumption on cutting speed are constructed for three cases:

1- provided $S^2t < 0.001$

2- provided $S^2t > 0.001$

3- provided $S^2t = 0.001$

From the analysis of the curves, it follows that during the finishing turning of structural steels, the specific energy intensity, depending on the cutting speed, changes as follows:

- when the condition $S^2t = 0.001$ is met, the specific energy consumption does not depend on the cutting speed /e = const/;
- at $S^2t < 0.001$, with an increase in cutting speed, the specific energy consumption also increases;
- at $S^2t > 0.001$, with increasing cutting speed, the specific energy consumption decreases.

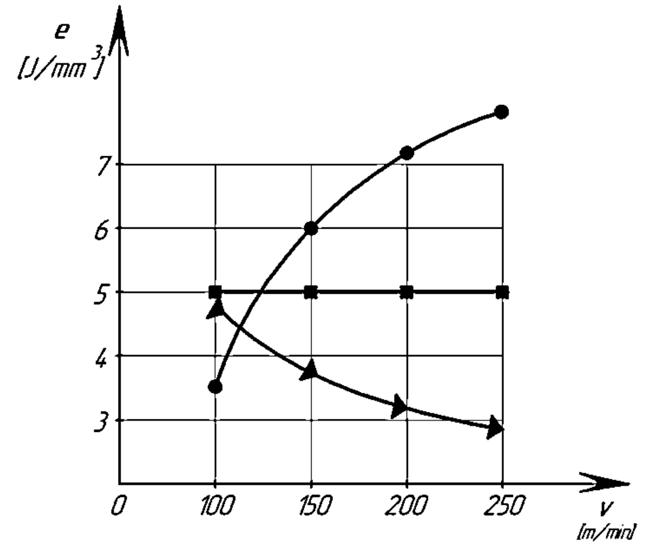


Fig.1. Influence of cutting speed V on specific energy consumption e in turning structural steels

●-1-t=0.1 mm, S=0.05 mm/rev, HB=200

▲-2-t=0.3 mm, S=0.1 mm/rev, HB=200

■-3-t=0.1mm, S=0.1 mm/rev, HB=200

On fig. 2. shows the areas of change in feed and depth of cut, corresponding to a decrease /I/ and an increase /II/ in specific energy consumption with increasing cutting speed. When turning with modes corresponding to curve *A*, with an increase in cutting speed, the specific energy consumption is a constant value.

A typical effect of cutting speed on the chip formation process can be characterized by the diagram in fig. 3.

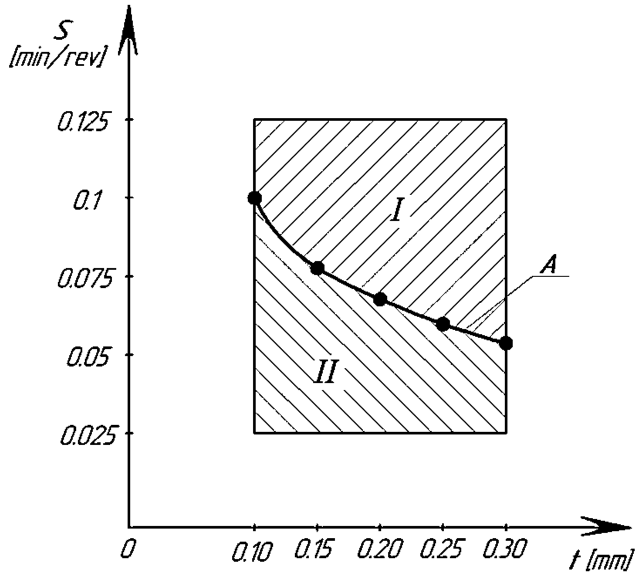


Fig.2. The areas of change in feed *S* and depth of cut *t* correspond to a decrease (I) and an increase (II) in specific energy consumption *e* with an increase in cutting speed *V*, when cutting structural steels.

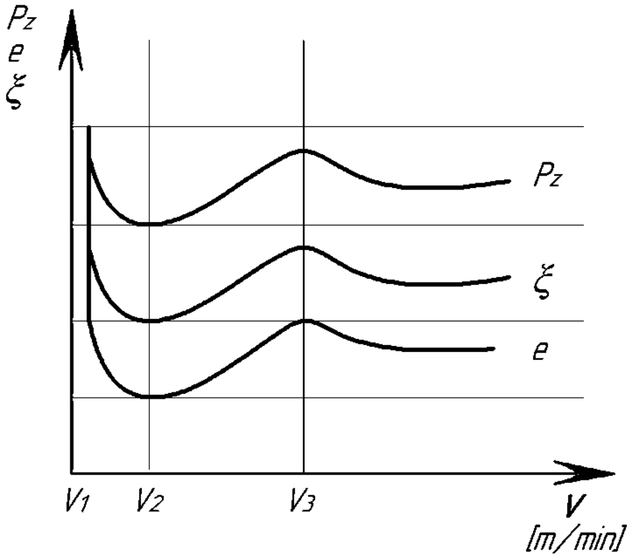


Fig.3. Scheme of the typical effect of cutting speed on chip settling, vertical projection of cutting force and specific energy consumption when cutting steel with a small rake angle.

According to the scheme, chip shrinkage and cutting forces, starting from a certain low cutting speed V_1, decrease with increasing cutting speed. This drop continues until cutting speed V_2, at which cutting forces and chip settling reach a minimum. A further increase in cutting speed leads to an increase in cutting forces and chip shrinkage, which continues up to the cutting speed V_3, where the cutting forces and chip shrinkage become maximum. Finally, as the cutting speed increases above V_3, the cutting forces and chip shrinkage begin to fall, and this fall, gradually fading, continues up to the highest cutting speeds.

Since chip shrinkage reflects the value of the specific work of chip formation, the nature of the change in specific energy intensity coincides with the change in the value of chip shrinkage with increasing cutting speed.

Velocity values V_1, V_2, V_3 (Fig. 3.) depend on the thickness and width of the cut, the properties of the processed and tool materials, and the geometric parameters of the cutter.

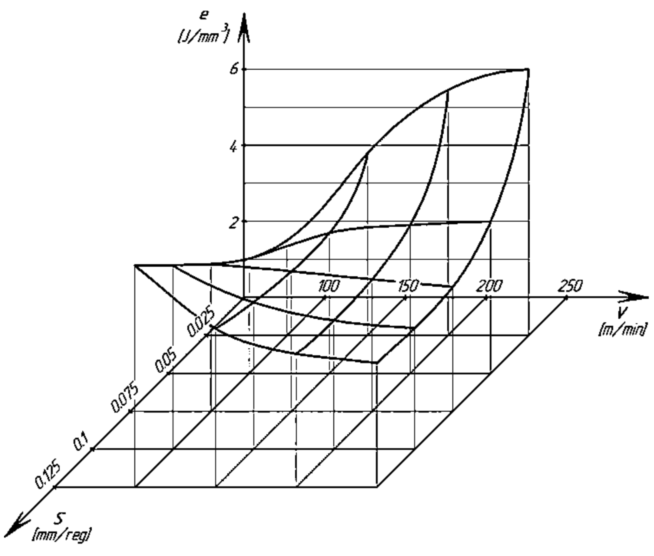


Fig.4. Dependence of specific energy consumption on feed *S* and cutting speeds *V*.

t=0.2 mm, HB=200, steel.

Studies have shown that the typical effect of cutting speed on the chip formation process occurs at large thicknesses of cuts, a > 0.147.

For small cut thicknesses, there is only one maximum chip shrinkage - in the region of high cutting speeds. The thinner the cut, the more this maximum is shifted towards high cutting speeds. Reducing the ratio of the cut width to its thickness (less than 3÷5) also shifts the maximum chip shrinkage towards higher speeds.

When turning structural steels with cutting conditions corresponding to the II zone, the cut thickness is small and varies from 0.071 mm to 0.018 mm. The ratio of cut width to thickness varies from 1.9 to 20. In this case, the maximum chip shrinkage, i.e. the maximum specific energy intensity is shifted towards cutting speeds of more than 250 m/min. In the speed range below this value, chip shrinkage and specific energy consumption increase with increasing cutting speed, which is confirmed by experimental studies (Fig. 1).

When turning structural steels with cutting conditions corresponding to zone I, with an increase in speed from 1.7 to 4.2 m/s, the specific energy consumption decreases, which is a typical effect of speed on the chip formation process. In this case, the maximum chip shrinkage and specific energy intensity corresponds to a speed of less than 100 m/min.

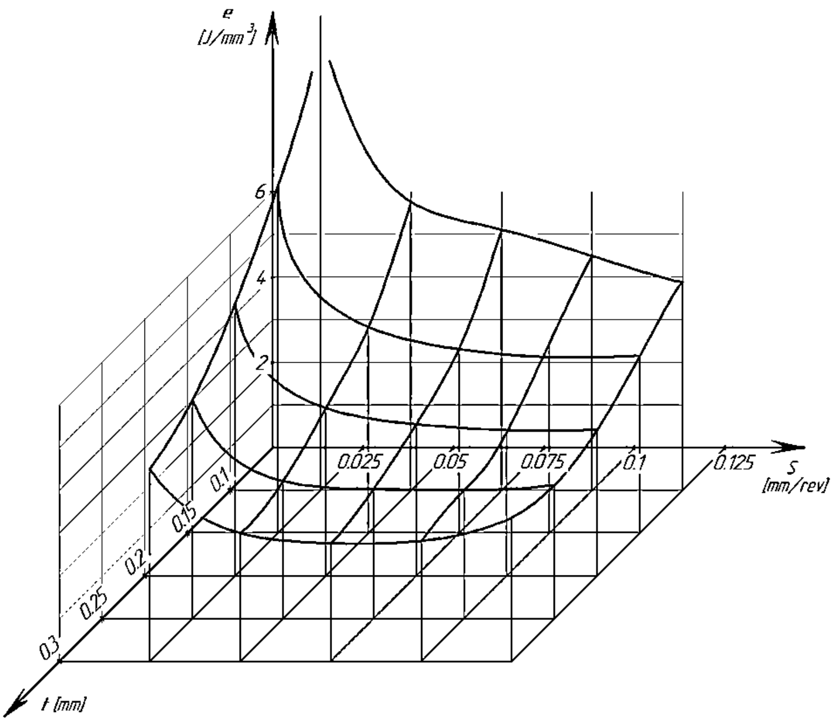


Fig.5. Dependence of specific energy consumption *e* on feed *S* and depth of cut t in steel turning. V=4.2 m/s, HB=200

On fig. 4 and 5 show the change in specific energy consumption from cutting modes. An analysis of the spatial curves shows that the change in the specific energy consumption depending on the cutting conditions is complex. The value of the specific energy consumption in the finishing turning of structural steels depends very much on the cutting speed, thickness and width of the cut. The analysis of the dependences of the specific energy consumption of the cutting process on the elements of the cutting mode confirms the information content of the signal in terms of power and its suitability for use in control systems for the process of machining machine parts.

References

1. Мамуров, Э. Т., Косимова, З. М., & Собиров, С. С. (2021). Разработка технологического процесса с использованием cad-cam программ. *Scientific progress*, *2*(1), 574-578.
2. Мамуров, Э. Т., Косимова, З. М., & Джемилов, Д. И. (2021). Повышение производительности станков с числовым программным управлением в машиностроении. *Science and Education*, *2*(5), 454-458.
3. Мамуров, Э. Т., Косимова, З. М., & Гильванов, Р. Р. (2021). Использование программ для расчетов основного технологического времени. *Scientific progress*, *2*(1), 918-923.
4. Мамуров, Э. Т., & Джемилов, Д. И. (2021). Использование вторичных баббитов в подшипниках скольжения на промышленных предприятиях. *Science and Education*, *2*(10), 172-179.
5. Мамуров, Э. Т. (2021). Металлларга кесиб ишлов беришда контакт жараёнларнинг виброакустик сигналга таъсири. *Science and Education*, *2*(12), 158-165.
6. Мамуров, Э. Т. (2021). Кесувчи асбоб ҳолатини ва кесиш жараёнини виброакустик сигнал асосида ташхислаш. *Science and Education*, *2*(12), 133-139.
7. Мамуров, Э. Т., & Одилжонов, Ш. О. Ў. (2021). Разработка рекомендаций по выплавке и заливки переработанного баббита в подшипники скольжения. *Scientific progress*, *2*(6), 1617-1623.
8. Косимова, З. М., Мамуров, Э. Т., & угли Толипов, А. Н. (2021). Повышение эффективности средств измерения при помощи расчетно-аналитического метода измерительной системы. *Science and Education*, *2*(5), 435-440.
9. Юлчиева, С. Б., Негматов, С. С., Негматова, К. С., Мамуров, Э. Т., Мадаминов, Б. М., & Рубидинов, Ш. Г. У. (2021). ПОВЫШЕНИЕ КОРРОЗИОННОСТОЙКОСТИ КОМПОЗИЦИОННЫХ МАТЕРИАЛОВ С ДОБАВЛЕНИЕМ ПОЛИМЕРНЫХ ДОБАВОК. *Universum: технические науки*, (10-1 (91)), 48-52.
10. Мадаминов, Б. М., Юлчиева, С. Б., Негматова, К. С., Кучкаров, У. К., Рубидинов, Ш. Г. У., Негматов, С. С., ... & Мамуров, Э. Т. (2021). АНТИКОРРОЗИОННЫЕ КОМПОЗИЦИОННЫЕ СИЛИКАТНЫЕ МАТЕРИАЛЫ ДЛЯ ЗАЩИТЫ ОБОРУДОВАНИЙ ХИМИЧЕСКОЙ ПРОМЫШЛЕННОСТИ. *Universum: технические науки*, (10-3 (91)), 61-66.
11. Рубидинов, Ш. Ғ. Ў. (2021). Бикрлиги паст валларга совуқ ишлов бериш усули. *Scientific progress*, *1*(6), 413-417.
12. Qosimova, Z. M. (2021). Influence of The Design of The Rolling Roller on The Quality of The Surface Layer During Plastic Deformation on the Workpiece.
13. Рубидинов, Ш. Ғ. Ў., & Ғайратов, Ж. Ғ. Ў. (2021). Штампларни таъмирлашда замонавий технология хромлаш усулидан фойдаланиш. *Scientific progress*, *2*(5), 469-473.
14. Рубидинов, Ш. Г. У., & Ғайратов, Ж. Г. У. (2021). Кўп операцияли фрезалаб ишлов бериш марказининг тана деталларига ишлов беришдаги унумдорлигини тахлили. *Oriental renaissance: Innovative, educational, natural and social sciences*, *1*(9), 759-765.
15. Рубидинов, Ш. Ғ. У., Қосимова, З. М., Ғайратов, Ж. Ғ. У., & Акрамов, М. М. Ў. (2022). МАТЕРИАЛЫ ТРИБОТЕХНИЧЕСКОГО НАЗНАЧЕНИЯ ЭРОЗИОННЫЙ ИЗНОС. *Scientific progress*, *3*(1), 480-486.

16. Mamatov, S. A. (2022). Paint Compositions for the Upper Layers of Paint Coatings. Middle European Scientific Bulletin, 23, 137-142.
17. Рубидинов, Ш. Ғ. У., Ғайратов, Ж. Ғ. У., & Райимжонов, Қ. Р. Ў. (2021). ИЗНОСОСТОЙКИЕ МЕТАЛЛОПОДОБНЫЕ СОЕДИНЕНИЯ. Scientific progress, 2(8), 441-448.
18. Тешабоев, А. Э., Рубидинов, Ш. Ғ. Ў., Назаров, А. Ғ. Ў., & Ғайратов, Ж. Ғ. Ў. (2021). Машинасозликда юза тозалигини назоратини автоматлаш. Scientific progress, 1(5).
19. Рубидинов, Ш. Ғ. У., & Раимжонов, Қ. Р. Ў. (2022). ИЗМЕНЕНИЕ МИКРОРЕЛЬЕФА ПОВЕРХНОСТИ И ШЕРОХОВАТОСТИ ДОПУСКОВ ДЕТАЛЕЙ ПОСЛЕ ХИМИЧКЕ-ТЕРМИЧЕСКИЙ ОБРАБОТКИ БОРИРОВАНИЯ. Scientific progress, 3(1), 34-40.
20. Mamirov, A. R., Rubidinov, S. G., & Gayratov, J. G. (2022). Influence and Effectiveness of Lubricants on Friction on the Surface of Materials. CENTRAL ASIAN JOURNAL OF THEORETICAL & APPLIED SCIENCES, 3(4), 83-89.
21. Рубидинов, Ш. Ғ. У., Ғайратов, Ж. Ғ. У., & Ахмедов, У. А. У. (2022). МАТЕРИАЛЫ, СПОСОБНЫЕ УМЕНЬШИТЬ КОЭФФИЦИЕНТ ТРЕНИЯ ДРУГИХ МАТЕРИАЛОВ. *Scientific progress*, *3*(2), 1043-1048.